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Voxel-based ΔTCP distribution:a tool to study the impact of dose distributions in tumour outcome

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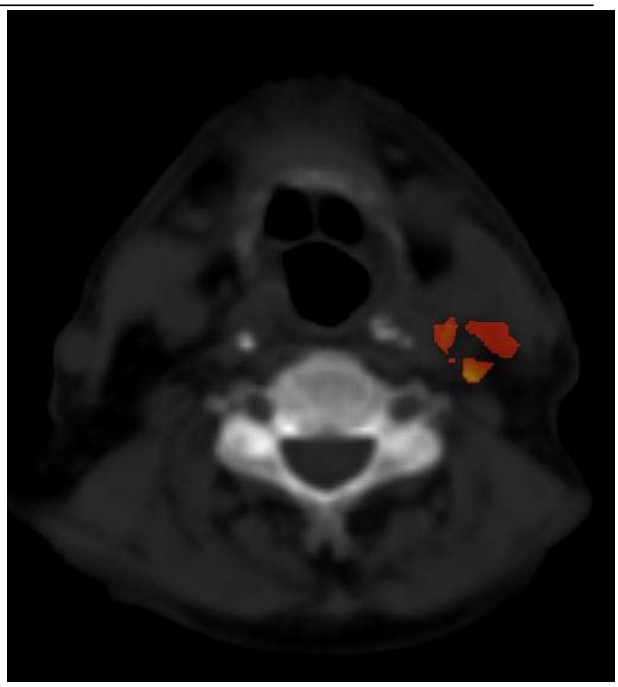
Purpose or Objective: The aim of this study is to create a tool to evaluate the effect of radiosensitivity parameterization and dose distributions on the local Tumour Control Probability (TCP). This tool will be an extension of the ΔTCP method by Sánchez -Nieto and Nahum1 without missing the spatial information associated to the dose volume histograms (DVH)

Material and Methods: In ref [1] it was shown, that the use of a voxel control probability (VCP) distribution is not a correct approach to discretize the effect on TCP of dose inhomogeneity throughout the tumour. Alternatively, the concept of the ΔTCP using the information of the bins of the DVH was proposed and proved to be a better solution.
Based on this concept and due to the advances made on the last 15 years in terms of computational calculation time, access to individual patient information regarding radiosensitivity and 3D dose distribution maps, we propose a ΔTCP voxel-based model.
The first step for generating the mentioned distribution map is to identify, by means of functional images, three regions with different oxygenation status (normoxic, hypoxic and necrotic regions) to which oxygenation histograms [2] are assigned. Secondly, a radiosensitivity value α is initially assigned to the system and modified for every voxel taking into account the oxygen parametrization (α'). Moreover, patient-to-patient variabilities are considered using a σα around the initial value so that the final distribution of effective radiosensitivity values (i.e., including the oxygen status) produce a response curve with a clinically meaningful steepness. Then, VCPs are calculated for the planned dose distribution according to the expression in [1]. A second set of VCPs are calculated for a different reference dose distribution (e.g., a completely homogeneous dose through the tumour or an optimized one after a dose painting approach).
Finally, theΔTCP for every (i,j,k) voxel, representing the impact on the final TCP of that voxel having a tested dose (Dt) instead the reference one (Dr) is computed as:
$\Delta TCP_{ijk}=\Sigma_x TCP(\alpha'x)\,[1-VCP_{ijk}(\alpha'x, Dr)/VCP_{ijk}(\alpha'x, Dt)]$
Where α'x the oxygen-corrected initial α value and TCP(α'x) is calculated as the multiplication of all the VCPs for α'x , for the tested dose distribution.

Results: The tool was tested using a H&N patient from Artfibio project[3]. As a result theΔ TCP distribution shown on the image was obtained. A dose distribution chosen to have a low local control (to highlight the tool functionality) and as reference an homogeneous 2 Gy dose per fraction to the GTV for 32 fractions were used.



Conclusion: It was shown that this could be a useful tool. As expected due to the small influence of single voxel dose variabilities on the total TCP, it is necessary to think on a future steps using megavoxels define within a certain threshold of oxygen level, dose and any relevant parameter.
References.
1 IJROBP 44(2):369-380,1999
2 Med. Phys. 40, 081703 (2013)
3 Comput Math Methods Med. 2015:103843

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Cranial stereotactic trajectory optimization via patient-specific overlap atlas

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Purpose or Objective: This study examines potential dosimetric improvements in cranial stereotactic radiotherapy plan quality by using a geometric optimization approach to reduce dose to organs-at-risk.

Material and Methods: Using previously delivered cranial stereotactic radiotherapy plans treated at the Nova Scotia Cancer Centre (NSCC), we have redesigned the treatment geometry to find an optimal couch rotation position based on a two-step process involving novel algorithms which reduce the presence of dose in surrounding organs at risk of exposure (OARs). Maintaining the gantry start/stop orientation from the conventionally designed treatment, the couch position is optimized based on a cost function analysis of accumulation of overlap score from an equation developed by Yang et al. [2] and refined by MacDonald et al. [1]. The score equations are used to generate 2D patient overlap atlases that are inform trajectory design. The algorithm incorporates factors for depth of both organs at risk (OAR) of exposure and target (PTV) volumes, and radiation dose sensitivities of each OAR. A further step is then implemented to focus on an individual OAR in need of further reduction after initial optimization. This algorithm applies an urgent sparing factor to the specified OAR, whose purpose is to maximize dose gradient between OAR and PTV, while minimally affecting the dose reduction effects to others.

Results: The optimization was conducted recursively on twenty plans for previously treated acoustic neuroma patients. Maximum and mean doses to the OARs were reduced by 37.03% ± 2.48% and 42.25% ± 1.62% respectively